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# FINAL REPORT

# NORTHFORK BURN STUDY

by

J.M. MILLER
Senior Entomologist

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Forest Insect Laboratory
Stanford University, California
March 28 1929

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# FINAL REPORT

# NORTHFORK BURN STUDY

## SUMMARY

### 1. Conditions at Time of Fire

This burn is typical of many which have occurred on the western slopes of the Sierra Nevada, where fires coming in from the lower brush areas attack the front of the yellow pine type with great severity. As a result of this and similar fires within the past 25 years the forest type has receded from the 2500- and 3000-foot to the 4500- and 5000-foot elevations and a number of points on the Sierra Forest.

a. Date of Northfork fire: June 22 to 27, 1924.

b. Weather Conditions: Low humidity accompanied by winds produced conditions favorable for severe crown fires where slopes and cover material were suitable.

c. Area Burned Over:

| | |
|---|---|
| By light ground fire | 3790 acres |
| " medium crown fire (less than 25% of stand fire-killed) | 1300 " |
| " severe crown fire (more than 50% of stand fire-killed) | 370 " |
| Total | 5460 " |

d. Cover Type:
Typical of border type, ranging from brush to fair quality yellow pine. Site quality of yellow pine mainly III and IV, with oak well distributed in understory; a very small per cent of sugar pine and white fir at higher elevations.

e. Stand:
Estimated at 19,110,000 f.b.m. merchantable, mainly yellow pine.

### 2. Extent of Damage from Fire

The varying intensity of the fire, due to variations of topography, inflammability of cover and time of fire, resulted in a wide range of injury to trees and brush cover.

The most readily recognizable phase of injury to trees was the amount of foliage burned off or scorched. The amount of cambium killing by heat around basal scars and on the trunk and limbs could not be accurately determined, and was taken into account only on the more severely-burned trees. From estimates based on sample plots and sample strips, the volume of timber on the burn was grouped according to degree of fire injury in the following classes:

| | | Per Cent of Total Stand by Trees | Per Cent of Total Stand by Volume |
|---|---|---|---|
| Class I. | No visible fire injury | 14.1% | 17.2% |
| II. | Less than 25% of lower crown defoliated | 28.3 | 44.3 |
| III. | From 25 to 50% of crown defoliated | 16. | 15.6 |
| IV. | From 50 to 75% of crown defoliated | 17.1 | 14.6 |
| V. | 75 to 100% defoliated; terminals not killed; cambium green | 14.5 | 5.1 |
| VI. | 100% defoliated; terminal buds killed; cambium severely scorched; fire-killed | 10. | 3.2 |
| | Total | 100% | 100% |

3. General Developments on Burn Following Fire

1924. Aside from trees killed by the fire, an additional 3.5% of the stand was killed before the close of this season, mainly by barkbeetles concentrating in the more severely injured trees of Classes IV and V. Growth conditions for the season were highly unfavorable, due to the drought of the preceding winter and spring.

1925. Practically all trees surviving until the spring of this season put out new needle growth. During the course of the summer a high per cent of the trees in Classes IV and V were attacked and killed by barkbeetles and were conspicuous by yellowing of the new foliage in August and September. The loss for this season totaled 3,698,000 f.b.m., or about 20 per cent of the stand left on the burn; 79% of the total losses for the five seasons following the fire occurred during 1925.

1926. This season was marked by a great decline in barkbeetle infestation. The volume of timber killed (about 2.6 per cent of the remaining stand) was less than that for 1924. The attacks for this season predominated in surviving trees of Class III.

1927 and 1928. Barkbeetle infestation during these two seasons was of an endemic character corresponding to that preceding the fire. Surviving trees in Classes III and IV were largely selected for attack. The more severely defoliated trees still surviving to October 1928 were slowly recovering the normal amount of foliage and growth rate.

The approximate per cent of loss and survival by volume during the period 1924 to 1928 inclusive stands as follows:

| | Per cent of Total Stand by Volume |
|---|---|
| Killed by the fire (1924) | 3.2% |
| " insects, mainly barkbeetles | 24.8 |
| Surviving (October 1928) | 72. |
| | 100.% |

The per cent of volume killed in each class surviving the fire was also determined as follows:

| | | Per cent of Class Dying Subsequent to Fire (Volume) |
|---|---|---|
| Class I. | No injury | .9% |
| II. | Less than 25% defoliation | 7. |
| III. | 25% to 50% " | 51.6 |
| IV. | 50% to 75% " | 76.9 |
| V. | 100% " | 44.2 |

## 4. Insect Infestations Developing After Fire

A number of species of cambium-feeding insects (Cerambycid and Buprestid borers) were abundant in the fire-killed trees within a few weeks after the fire occurred.

The red turpentine beetle came into the burn soon after the fire and attacked the green cambium of many fire-injured trees. These attacks were rarely fatal to the tree unless followed by other barkbeetles.

The western pine beetle was the most important and abundant insect connected with the killing of trees which survived the fire. By volume of trees attacked within the burn it increased 735% in 1924 over 1923; in 1925 the increase was 454% over 1924, the volume killed being 4535% greater than in 1923. In 1926 the volume killed decreased 88% from that of 1925, the 1926 volume being about half that of 1924 but about 4 times as large as that of 1923. In 1927 and 1928 the infestation was endemic on the burn, and except for a few fire-weakened trees that were attacked was quite similar to that which existed on the area before the fire.

The concentration of the western pine beetle on the burn in 1924 and 1925 did not appear to influence the cycle of the infestation on adjoining areas, where the volume killed also increased in 1924 and 1925 and decreased in 1926. However, the volumes of the increase and subsequent decrease on the burn were far in excess of any that occurred on adjoining areas. This indicates that the fire produced conditions which were especially attractive or favorable to the western pine beetle, and which persisted for two seasons following the fire.

On the basis of a limited amount of bark surface examined, conditions for brood development of the western pine beetle were found to be unfavorable in the fire-weakened trees, especially in those only partially defoliated by the fire (Class III). This indicates that the infestation which builds up on a burn in weakened trees is not of an aggressive character and is short-lived after the supply of susceptible trees becomes exhausted.

## 5. Relation of Barkbeetle Attack to Growth Conditions in Fire-Weakened Trees

An analysis of the growth rings in surviving trees on sample plots shows that a marked suppression of growth occurred in all fire-defoliated trees during the four seasons subsequent to the fire. This condition of unfavorable growth was further aggravated by severe drought during the season of 1924.

It was found that many trees failed to form any visible ring in 1925 and that some trees still surviving in 1928 had not formed a normal growth ring since the fire. It was also found on sample strips that 96% of trees killed during the seasons of 1924, 1925 and 1926 had made little or no growth since the fire.

6. Attraction of Western Pine Beetle to Fire-Weakened Trees

A controlled-burning experiment carried out in 1927 indicates that the western pine beetle is not attracted to fire-scorched trees as a result of odors, heat or other influences due directly to the fire. Trees scotched in April did not attract the beetles until late in August. Apparently the checking of growth by defoliation, which lowers the resistance of the tree and renders it specially susceptible to attack, is the most important factor in the selection of fire-weakened trees by barkbeetles. There is therefore only an indirect relation between fire injury and western pine beetle attack, depending upon the extent to which the fire reduces the growth rate of the tree through defoliation and cambium injury.

The character of the fire and the resultant injury to individual trees in a large measure determines the subsequent amount of western pine beetle infestation on burns in the yellow pine type.

## BASIS FOR FINAL REPORT

A preliminary report of this study was submitted May 23, 1927, which included data collected up to the close of the 1926 season. The more important points covered in this report were:

1. Conditions and character of the fire of June 22, 1924

2. Classification and estimates by trees and volume of the amount of fire injury

3. Amount of beetle-killed timber on area of burn, 1919 to 1923 inclusive (prior to fire)

4. Amount of beetle-killed timber on area of burn subsequent to fire, June 1924 to September 1925

5. Summary of data from three selected sample plots of 100 trees each

6. Summary of data from 2.3 miles of 2-chain strip surveys run through the burn area

7. A survey of the entire area of burn, in which all trees dead or attacked by insects up to September 1925 were marked according to three recognized types, representing different intensities of fire injury

Since this preliminary report was submitted a recruise of the burn area was made during May and June 1927, and all trees killed since the first survey were marked; annual examinations of the sample plots were made in October 1927 and October 1928; and a recheck of the sample strips was made in October 1928.

The greater part of the field work involved in the surveys of the burn was under the immediate supervision of H.L. Person, assisted by Albert Wagner.

The present report incorporates the data secured during 1927 and 1928 with that previously presented. This rounds out the study so as to cover developments during five seasons subsequent to the fire. It is now obvious that the main factors influencing barkbeetle infestations within the burn area have subsided, and that further intensive studies on this burn will yield very little supplementary information of value. No further field work is contemplated except for occasional examinations of the sample plots to check recovery of certain trees and ultimate restocking of these plots.

## SUMMARY OF FIRE-KILLED, FIRE-INJURED AND INSECT-KILLED TIMBER ON BURN

In the following table the amount of timber in each class of fire injury are estimates based on sample-strip data. The amount killed by beetles is based on a 100% cruise of the burn which included all trees attacked up to the close of the 1926 season:

| Class | Total Volume on Burn after Fire | | Total Killed | | % of Class killed by Volume |
|---|---|---|---|---|---|
| | Trees | Volume | Trees | Volume | |
| I. No injury to tree | 2,883 | 3,286,920 | Insects 32 | 29,490 | .9% |
| II. Less than 25% of crown defol. by fire | 5,898 | 8,465,730 | " 639 | 594,690 | 7. % |
| III. 25 to 50% of crown defol. by fire | 3,268 | 2,981,160 | " 1,588 | 1,545,840 | 51.6% |
| IV. 50 to 75% of crown defol. by fire | 3,509 | 2,790,060 | " 2,307 | 2,144,500 | 76.9% |
| V. 75 to 100% of crown defol. term. buds & cambium green | 2,452 | 974,610 | " 421 | 431,040 | 44.2% |
| VI. 100% of crown defol. cambium scorched; term. buds killed | 2,011 | 611,520 | Fire-killed 2,011 | 611,520 | 100. % |
| Total | 20,021 | 19,110,000 | 6,998 | 5,357,080 | 28. % |

This table is shown graphically in Chart No. 1.

One apparent inconsistency in the per cent killed by beetles may be found in the 76.9% killed in Class IV, while in Class V, which was more severely defoliated, the percentage killed is only 44.2%. The explanation seems to lie in the fact that the beetles obviously killed trees of larger diameters, while the smaller trees recovered. Class V had a much higher percentage of small trees, and the beetles selected only the larger trees which this class included. This is shown by the following analysis:

| | Average Volume, All Trees in Class | Average Volume, Beetle-Killed Trees in Class |
|---|---|---|
| Class IV | 795 b.f. | 929 b.f. |
| " V | 324 " | 1,023 " |

These averages do not include trees under 10 inches d.b.h., which were not considered merchantable. Including poles under 10" the average volume of Class IV trees was 643 bd feet and that of Class V 194 bd.ft. (see Sample Strip data). A ground fire may entirely scorch the foliage of a small vigorous tree because of its low height, but still leave it in a condition capable of subsequent growth and recovery. It may therefore retain considerable resistance to beetle attack. A large tree is usually defoliated only by a severe crown fire which not only scorches the foliage but causes some killing of cambium in the upper trunk and limbs. The larger trees therefore are more severely injured, and because of much slower growth rate become quite susceptible to beetle attack.

Still another consideration is the fact that the western pine beetle rarely attacks the smaller trees of the stand under normal conditions, but shows a preference for trees of diameter groups between 20 and 30 inches. The majority of Class V was composed of trees under 20".

## DISTRIBUTION OF BEETLE-KILLED TIMBER BY FIRE-INJURY CLASSES DURING 1924, 1925 and 1926

The progress of the beetle infestation during the three seasons following the fire is shown in the following table:

Table II
Distribution of Beetle-Killed Timber by Fire-Injury Classes
1924-1926 Inclusive

| Class of Fire Injury | 1924 | | 1925 | | 1926 | |
|---|---|---|---|---|---|---|
| | Trees | Volume b.f. | Trees | Volume b.f. | Trees | Volume b.f. |
| I | -- | -- | 20 | 23,560 | 12 | 5,930 |
| II | 45 | 32,260 | 549 | 517,270 | 45 | 45,160 |
| III | 136 | 118,310 | 1,219 | 1,223,140 | 233 | 204,390 |
| IV | 302 | 336,700 | 1,849 | 1,683,550 | 156 | 124,250 |
| V | 159 | 179,140 | 258 | 250,520 | 4 | 1,380 |
| Totals | 642 | 3,666,410 | 3,895 | 3,698,040 | 450 | 381,110 |

These figures, representing the beetle-killed trees together with the fire-killed timber, are shown graphically in Chart II. They show a heavy building-up of barkbeetle infestation which reached its maximum in 1925, the second season following the fire. The season of 1926 was marked by a great decline in losses, the total volume being considerably less than that for 1924. It is apparent that by the third season following the fire the supply of trees weakened by fire injury was becoming exhausted and the beetle population was returning to its pre-fire status.

## DISTRIBUTION OF BEETLE KILLED TIMBER BY TYPE OF BURNED AREA

In the survey made in 1925 the entire area of the burn was mapped according to the intensity of the fire. Four distinct types of burn were recognized. Type I, representing no fire damage, or areas missed by the fire within the boundaries of the burn, did not occur on the Northfork Burn. Type II represents a light ground fire, Type III a partial crown fire, and Type IV a severe crown fire where more than 50% of the trees were fire-killed.

Table III
Distribution of Beetle-Killed Timber by Type of Burn

| Year | TYPE II Light Ground Fire 3790 Acres | | | TYPE III Medium Crown Fire 1500 Acres | | | TYPE IV Severe Crown Fire 370 Acres | | |
|---|---|---|---|---|---|---|---|---|---|
| | Trees | Volume bf | Loss per Acre | Trees | Volume bf | Loss per Acre | Trees | Volume bf | Loss per Acre |
| 1924 | 184 | 262,800 | 69 | 357 | 324,200 | 249 | 101 | 79,810 | 216 |
| 1925 | 1134 | 1,241,530 | 328 | 2388 | 2,159,130 | 1661 | 373 | 296,980 | 800 |
| 1926 | 130 | 127,030 | 34 | 274 | 223,600 | 172 | 46 | 30,480 | 82 |
| Totals | 1448 | 1,631,360 | 431 | 3019 | 2,706,930 | 2082 | 520 | 407,270 | 1098 |

On Type IV the total loss per acre is only about half of that which occurred on Type III. This can readily be understood when it is recognized that a high per cent of the trees were fire-killed on Site IV and were not figured in the barkbeetle losses. Many of the fire-killed trees did not attract beetles. The tendency of the infestation was to build up on Site III, where only medium crown damage occurred, leaving a number of trees which survived the fire but were unable to recover their normal vigor and growth rate.

## COMPARISON OF CYCLE OF INFESTATION ON BURN AND ADJOINING CHECK AREA

Records are available showing the amount of yellow pine killed annually by barkbeetles on both the burn and the adjoining Cascadel Basin for the entire period 1919 to 1926 inclusive.

Table IV

Annual Volume of Beetle-Killed Yellow Pine

| Year | Northfork Burn Area 5460 Acres | | | Cascadel Area 1880 Acres | | |
|---|---|---|---|---|---|---|
| | No. Trees | Volume | Av.Loss per Acre | No. Trees | Volume | Av.Loss per Acre |
| 1919 | 213 | 136,120 | 24 | 76 | 87,620 | 46 |
| 1920 | 67 | 100,410 | 18 | 23 | 48,610 | 25.8 |
| 1921 | 61 | 86,640 | 16 | 42 | 49,470 | 26 |
| 1922 | 113 | 146,670 | 27 | 91 | 111,010 | 59 |
| 1923 | 34 | 79,780 | 14 | 35 | 43,710 | 23.7 |
| 1924 | 642 | 666,810 | 122 | 115 | 145,660 | 72 |
| 1925 | 3,895 | 3,697,640 | 677 | 388 | 405,480 | 217 |
| 1926 | 450 | 381,110 | 70 | 138 | 130,640 | 69 |

A graph comparing the progress of these losses is shown in Chart III. The total stand per acre was considerably higher on Cascadel than on the burn which included a considerable area of brush land. This explains the relatively higher loss per acre on Cascadel preceding the fire.

The outstanding point brought out by this comparison is that the cycle, both preceding and after the fire, was essentially the same on both areas. They differ mainly in the relative quantity of losses during the seasons of 1924, 1925 and 1926. The severe drought of 1924 resulted in a great increase of beetle losses throughout the Sierra pine belt which is reflected on the Cascadel area. This increase reached its peak in 1925 and a pronounced drop occurred in 1926. On the burn the increase of 1925 was boosted far beyond what would have occurred normally as a result of the drought alone. However, in 1926 the decrease was much greater than that which occurred in the outside area.

In the comparison of these two areas it is difficult to see where the beetle population within the burn was influenced by that outside or vice versa. Apparently the infestation built up locally within the burn during 1924 and 1925. Beetles were not attracted in to the fire-weakened trees to such an extent as to reduce the population on the adjoining area. Also, when the supply of fire-weakened trees was exhausted, the beetles within the burn did not spread to outside areas in sufficient numbers to change the natural decline in 1926.

## SUMMARY OF SAMPLE PLOT DATA

The preliminary report of 1925 presented all basic data for the three sample plots selected within the burn and developments on them up to October 1926. The object of these plots was to secure a series of records extending over a period of years from individual trees that were marked and tagged soon after the fire. The plots were not laid out by area, but consisted of 100 trees each, selected so as to represent all classes of fire injury occurring on burns of Tyles II, III and IV.. Each plot was examined annually and records secured from each tree, showing recovery, insect attacks etc. Increment cores were taken in October 1926 and again in October 1928. No trees below 4" d.b.h. were considered on these plots.

a. Survival of trees on sample plots

Table 5 summarizes records as to survival up to October 1928 for each plot.

TABLE 5

Summary of Killing and Survival of Trees on each Sample Plot 1924-1928

| | Classes of Fire Injury | | | | | | Total all Classes |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | |
| **Plot No.1. Inspector Tr.** | | | | | | | |
| (Heavy Crown Fire) | | | | | | | |
| Types III and IV | | | | | | | |
| Trees marked Aug. 1924 | | | 1 | 21 | 72 | 6 | 100 |
| Av. d.b.h. | | | 38" | 27" | 19.4" | 22.8" | 21.3" |
| Trees dying after fire: | | | | | | | |
| 1924 | | | | | 17 | 6 | 23 |
| 1925 | | | | 6 | 48 | | 54 |
| 1926 | | | | 6 | 5 | | 11 |
| 1927 | | | | | 1 | | 1 |
| 1928 | | | 1 | 3 | | | 4 |
| Total dead | | | 1 | 15 | 71 | 6 | 93 |
| Trees surviving Oct.1928 | | | | 6 | 1 | 0 | 7 |
| Per cent surviving | | | 0 | 28% | 1.4% | 0 | 7% |
| **Plot No.2, Pine Flat** | | | | | | | |
| (Light Crown Fire) | | | | | | | |
| Type II | | | | | | | |
| Trees marked Aug. 1924 | 21 | 42 | 19 | 11 | 7 | | 100 |
| Av. d.b.h. | 22.6" | 24.4" | 20.2" | 12.8" | 9.7" | | 20.94" |
| Trees dying after fire: | | | | | | | |
| 1924 | | | | | | | |
| 1925 | | | | 1 | | | 1 |
| 1926 | | | | | | | |
| 1927 | | | | | | | |
| 1928 | | | 2 | | 1 | | 3 |
| Total dead | | | 2 | 1 | 1 | | 4 |
| Trees surviving Oct.1928 | 21 | 42 | 17 | 10 | 6 | | 96 |
| Per cent surviving | 100% | 100% | 89.5% | 90.1% | 86% | | 96% |
| **Plot No.3.Peckinpah Mill** | | | | | | | |
| (Mixed gr.and cr. fire) | | | | | | | |
| Types II,III,IV | | | | | | | |
| Trees marked Aug. 1924 | 6 | 19 | 12 | 13 | 46 | 4 | 100 |
| Av. d.b.h. | 28.6" | 32.8" | 26.5" | 26.7" | 30.3" | 26.5" | 29.6" |
| Trees dying after fire: | | | | | | | |
| 1924 | | | | | | 4 | 4 |
| 1925 | | | 1 | | 34 | | 35 |
| 1926 | | | | 3 | 2 | | 5 |
| 1927 | | | | | 1 | | 1 |
| 1928 | | | | | | | |
| Total dead | | | 1 | 3 | 37 | 4 | 45 |
| Trees surviving Oct.1928 | 6 | 19 | 11 | 10 | 9 | 0 | 55 |
| Per cent surviving | 100% | 100% | 91.9% | 77% | 1.9% | 0% | 55% |

This comparison of the survival in the different classes of fire injury shows a wide variation among the three plots. It is obvious that by far the highest survival in Classes IV and V occurred on Plot 2, where these classes were composed mainly of small trees defoliated by a back fire which burned at night.

The survival for each class, combined for all plots, is shown in Table 6:

Table 6
Summary of Killing and Survival of Trees on Plots 1,2 & 3

| | Classes of Fire Injury | | | | | | Total all Classes |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | |
| Trees marked August 1924 | 27 | 61 | 32 | 45 | 125 | 10 | 300 |
| Av. d.b.h. | 23.9" | 27" | 23.1" | 23.3" | 22.8 | 24.2" | 23.6" |
| Trees dying after fire: | | | | | | | |
| 1924 | | | | | 17 | 10 | 27 |
| 1925 | | | 1 | 7 | 82 | | 90 |
| 1926 | | | | 9 | 7 | | 16 |
| 1927 | | | | | 2 | | 2 |
| 1928 | | | 3 | 3 | 1 | 0 | 7 |
| Total dead | | | 4 | 19 | 109 | 10 | 142 |
| Trees surviving Oct.1928 | 27 | 61 | 28 | 26 | 16 | 0 | 158 |
| Per cent surviving | 100% | 100% | 87% | 58% | 13% | 0 | 52.6% |

b. Character of Infestation on Sample Plots

A record was kept of primary and secondary insect attack, so far as it could be recognized on the lower trunk, for all trees on each plot. A summary of all causes which contributed to the death of the trees is shown in Table 7:

Table 7
Causes of Dying Trees, Plots 1,2,3
(to October 1928)

| | Number of Trees | Per cent of Trees |
|---|---|---|
| Killed by fire; Class VI | 10 | 3.3% |
| " western pine beetle | 80 | 26.8% |
| " mountain pine beetle | 1 | .3% |
| Primary attack doubtful; mixed infestation on main trunk of barkbeetles, Cerambycids and Buprestid borers | 51 | 17. % |
| Surviving | 158 | 52.6% |
| Total | 300 | 100. |

The other barkbeetles noted in the mixed infestation were mainly Ips oregoni, but this seemed to compose a very small part of the infestation on the burn. The Cerambycids and Buprestids were found only in the larval form, and no attempt was made to distinguish these by species in checking them on the tree records. The Cerambycids were considered to be mainly Rhagium lineatum, Graphisurus obliquus and Asemum mokelumne; the Buprestids, according to rearings by Dr. Burke, were Melanophila consputa, Melanophila gentilis and Chrysobothris caurina.

Another barkbeetle frequently noted was the red turpentine beetle, Dendroctonus valens. Attacks occurred near the base of many trees in the more severely fire-injured trees. However, recovery usually followed unless the tree was attacked by other insects. It is very doubtful if the attack of the turpentine beetle can be considered primary.

c. Cycle of Western Pine Beetle Infestation on Sample Plots

This insect predominated over all others in the killing of fire-injured trees, as it did on the entire burn. Practically all the trees of larger diameters were attacked by it, and in actual volume rather than in number of trees it accounted for at least 75% of the loss following the fire. A record of its attacks on the sample plots according to years is shown in Table 8:

Table 8
Western Pine Beetle Attacks on Sample Plots

| Fire Injury Class | Year of Attack | | | | | |
|---|---|---|---|---|---|---|
| | 1924 | 1925 | 1926 | 1927 | 1928 | Total |
| Class I | | | | | | |
| No. Trees Attacked | | | | | | |
| Class II | | | | | | |
| No. Trees " | | | | | | |
| ClassIII | | | | | | |
| No. Trees " | | 1 | | | 2 | 3 |
| Class IV | | | | | | |
| No. Trees " | 1 | 3 | 7 | | 3 | 14 |
| Class V | | | | | | |
| No. Trees " | 14 | 46 | | | | 60 |
| Class VI | | | | | | |
| No. Trees " | 3 | | | | | 3 |
| Total | 18 | 50 | 7 | | 5 | 80 |

This shows that the western pine beetle infestation began to build up in 1924, reached its peak in 1925, dropped to a low point in 1926 and failed to develop any attacks on the plots in 1927. It was, however, present in the burn during 1927 and killed a few trees outside of the plots. In 1928 three attacks again occurred on the plots in surviving trees of Classes III and IV.

A preference is clearly shown for trees of Class V, which represent the more severely injured trees that survived the fire. Attacks also occurred in the green strips of cambium of Class VI trees, but these were very irregular and scattered and were not counted as primary attacks on living trees.

## SUMMARY OF SAMPLE STRIP DATA

The basic data from 36.6 acres of two-chain strip surveys were included in the preliminary report. The first survey was made in September 1924. All standing trees within the strips were marked according to class of fire injury. A resurvey was made in October 1926, and records which included notes as to primary insect attack were taken from trees that had died since the fire. A third survey was made in October 1928, in which all trees originally marked were again checked.

These sample strips were selected for the purpose of securing a representative cross-section of the burn area. The loss figures were worked up on both a tree and volume basis.

a. Survival of Trees on Sample Strips

Table 9
Summary of Killing and Survival of Trees of Sample Strips to October 1928

| | Class of Fire Injury | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | Total |
| Trees Marked September 1924 | 80 | 155 | 85 | 89 | 102 | 86 | 597 |
| Av. Volume b.f. | 842 | 1121 | 719 | 643 | 194 | 148 | 822 * |
| Trees dying after fire: 1924 | | | | 4 | 16 | 86 | 106 |
| 1925 | | 5 | 14 | 31 | 44 | | 94 |
| 1926 | | 2 | | 2 | | | 4 |
| 1927 | | | 1 | | | | 1 |
| 1928 | | | 1 | 1 | | | 2 |
| Total Dead | | 7 | 16 | 38 | 60 | 86 | 207 |
| No. Trees Surviving Oct.1928 | 80 | 148 | 69 | 51 | 42 | 0 | 390 |
| Per cent of Survival | 100% | 95% | 81% | 56% | 41% | 0 | 65% |

*These averages include 177 poles under 10" d.b.h. which contained no merchantable volume.

It cannot be claimed that the strips, which represent only 1.3% of the total stand of the burn, give an accurate quantitative representation of the entire burn. However, the figures secured from the sample plots, sample strips and the entire burn show the same consistent tendencies, and the differences represented by quantitative figures do not materially affect conclusions.

b. Character of Infestation on Sample Strips

The insects primarily responsible for the loss following the fire, together with fire losses, are shown in Table 10.

Table 10

Cause of Dying Trees on Sample Strips

Summary by Number of Trees

| | No. Trees | % Trees |
|---|---|---|
| Killed by Fire, Class VI | 86 | 14 |
| " D. brevicomis | 71 | 11.9 |
| " D. monticolae | 2 | .3 |
| Attacked by other insects (borers, D. valens; primary attack doubtful) | 48 | 8. |
| Surviving | 390 | 65.8 |
| Total | 597 | 100.0 |

Summary by Volume

| | No. Trees | Volume | % Volume |
|---|---|---|---|
| Killed by Fire | 86 | 12,770 | 3. |
| " Insects | 121 | 51,750 | 13.2 |
| Surviving | 390 | 327,520 | 83.8 |
| | 597 | 392,040 | 100.0% |

The trees considered on the sample strips included diameter classes much smaller than those considered on the sample plots. This accounts largely for the high per cent of fire-killed trees on the strips and the lower per cent killed by the western pine beetle. Trees of pole sizes are rarely attacked by this beetle, and on the burn they apparently selected the larger trees that were severely scorched.

An analysis of the species attacking on the sample strips was essentially the same as that for the sample plots.

## DEVELOPMENT OF WESTERN PINE BEETLE BROODS IN FIRE-INJURED TREES

All records indicate the predominance of this barkbeetle in the killing of trees defoliated by the fire. Its ability to build up its numbers depends largely upon the success with which its broods are able to develop and emerge from fire-weakened trees.

No additional records have been secured on this point aside from those already presented in the original report. These records, taken from 20 selected trees in each class of fire injury, compare the number of beetles attacking with the number of emergence holes, which indicates the ratio of increase or decrease during the period of development within the trees.

The only consistent tendency shown by these counts is that the number of beetles attacking per square foot of bark decreased as the amount of fire injury increased. This supports the theory that the lowered resistance of the more severely injured trees makes it possible for a few beetles to establish their attack, and that the sap resistance of normal or slightly injured trees can be overcome only by a concentration of numbers of the beetles.

No consistent tendencies were uncovered by a comparison of the number of beetles emerging with the number of parents attacking. The table on Page 9 of the preliminary report shows that in Class III the number of beetles emerging was less than the number of their parents. In trees of Classes II, IV and V some increase occurred, but this is less than the normal ratio developed by brood studies on other areas, where the average is around 64 beetles emerging for 22 attacking. The greatest increase on the burn occurred in Class VI, where 20.6 beetles emerged for each 6.5 which attacked, a ratio of about 3 to 1, or approximately the normal. The ratio in Class V is about 2 to 1. This would indicate that the beetles built up their numbers largely in the more severely injured trees, which were attacked the first season following the fire; and that the partially defoliated trees in Classes III and IV, which composed the bulk of the attack during the second season following the fire, were unfavorable to brood development. The high mortality in trees of these classes may account for the decline of the infestation in 1926.

The attacks on Class VI trees were very irregular, occurring mainly in green strips of cambium on the side away from the heaviest fire damage. The wide variation both in numbers attacking and emerging in all classes throws considerable question on the averages that were secured. The counts include a total of about 1400 square feet of bark from 100 trees, and a much larger quantity would be necessary as a basis for reliable conclusions as to what actually transpired on a quantitative basis for the entire burn.

## RELATION OF BARKBEETLE ATTACK TO GROWTH RATE OF FIRE-INJURED TREES

In the preliminary report considerable attention was given to growth conditions in trees surviving the fire. It was shown that many trees in Classes IV and V had failed to make any appreciable growth up to the close of the 1926 season on both the sample plots and strips. In certain trees on the plots evidence of the annual rings was entirely lacking except in the growth callus made around the scar where the tree was blazed in marking. These last rings were noted on a number of trees on Plots 1 and 3 where the crown fire damage was severe; but on Plot 2, where the damage was caused by a light ground fire, the rings were present in practically all trees. (See Plate I, page 24)

To follow up this phase of the study cores were taken from all surviving trees in October 1928 on the sample plots. The cores for Plots 1 and 3 were found to be unsatisfactory because of the fact that the annual rings put on since the fire could not be positively identified where certain rings were missing. Only in chips taken from one edge of the marking scar could the year of growth be definitely assigned. These chips were taken from trees on Plot 1 only.

The ring for 1924 was extremely short in all trees outside of the burn, due to the drought of that season. Undoubtedly within the burn the suppression of growth for that season represents the combined effect of both drought and fire injury. It seems impossible to isolate the amount of suppression due to the drought alone. Something might be gained by comparison with the rings in trees outside of the burn, but here we know little of the variation in soil-moisture conditions between burned and non-burned cover. Considering all the other variables we can only assume that the pronounced setback in growth during the period following 1924 on the plots was due mainly to fire injury.

On Plot 2, where the injury resulted from backfiring at night, average growth records are shown for all classes in Table 11.

Table 11
Average Growth Rate for Each Class of Fire Injury
of Trees Surviving after October 1926
Plot 2 (Pine Flat)

| | No. Trees | Width of Annual Growth Ring in MM. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1919 | 1920 | 1921 | 1922 | 1923 | 1924 | 1925 | 1926 | 1927 | 1928 |
| Class I: | 21 | 1.15 | 1.14 | 1.11 | .97 | 1.79 | .64 | 1.03 | .85 | .98 | 1.20 |
| Class II: | 42 | 1.86 | 2.05 | 2.12 | 1.66 | 3.22 | 1.21 | 1.86 | 1.48 | 1.74 | 1.85 |
| Class III: | 17 | 1.28 | 1.50 | 1.51 | 1.40 | 2.36 | 1.18 | 1.21 | 1.26 | 1.29 | 1.55 |
| Class IV: | 10 | 1.22 | 1.30 | 1.60 | 1.42 | 2.65 | 1.09 | .68 | 1.08 | 1.13 | 1.18 |
| Class V: | 6 | .88 | .96 | .99 | .79 | 1.46 | .43 | .38 | .15 | .38 | .44 |

The growth curves for these groups are shown in Chart IV.

Classes I and II show little suppression of growth which can be attributed to fire injury. Classes III and IV show some suppression during 1925 and 1926, but during 1927 and 1928 apparently recovered their normal vigor. Class V, represented by a group of 6 small trees, shows the greatest suppression, and up to 1928 had not regained the pre-fire growth average.

As there was no thinning of the stand as a result of the fire, release of growth is not to be expected on this plot.

On Plot 1 chips were secured from 6 trees still living in October 1928 and 4 trees killed by insects in 1927 and 1928. This plot was burned by a severe crown fire which severely defoliated all trees. The subsequent thinning of the stand by dying of trees in 1924 and 1925 gave an opportunity for release of the few survivors on the plot.

Growth measurements of each tree are shown in Table 12, and the growth curves are shown in Chart V.

Table 12

Growth Rate Trees Surviving after 1926

Inspector Trail Plot

Living Trees

| Tree No. | DBH | Cl. | Width of Annual Ring in MM. 1919 | 1920 | 1921 | 1922 | 1923 | 1924 | 1925 | 1926 | 1927 | 1928 | Condition Oct. 1928 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 49 | 18" | IV | 1.75 | 1.40 | 2.00 | 1.31 | 1.96 | .72 | 0 | 0 | .14 | .15 | Living |
| 89 | 26" | IV | .71 | .82 | 1.00 | .53 | 1.17 | .54 | 0 | 0 | .65 | .42 | " |
| 95 | 20" | IV | .88 | .80 | .90 | .79 | .95 | .48 | 0 | .16 | .21 | .38 | " |
| 96 | 32" | IV | .74 | .87 | .60 | .57 | 1.20 | .27 | 0 | 0 | .18 | .19 | " |
| 97 | 36" | IV | 3.05 | 2.46 | 1.84 | 1.57 | 6.71 | 2.14 | .24 | .64 | 1.85 | 1.57 | " |
| 22 | 12" | V | 3.37 | 2.88 | 2.46 | 2.50 | 4.00 | 1.72 | .27 | .85 | .70 | 2.80 | Living |
| | Total | | 10.50 | 9.23 | 8.80 | 7.27 | 15.99 | 5.86 | .51 | 1.65 | 3.73 | 5.51 | |
| | Aver. | | 1.75 | 1.54 | 1.47 | 1.21 | 2.66 | .98 | .08 | .27 | .62 | .92 | |

Dead Trees

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 94 | 38" | III | .45 | .80 | .89 | .71 | .95 | .47 | 0 | 0 | 0 | 0 | Killed by D.b. 9/28 |
| 47 | 16" | IV | .69 | .55 | .61 | .61 | .99 | .25 | 0 | 0 | .07 | | Killed by D.b. 8/27 |
| 75 | 22" | IV | 2.90 | 2.55 | 2.67 | 2.32 | 3.73 | 1.57 | 0 | 0 | 0 | 0 | Killed by D.b. 7/28 |
| 92 | 40" | IV | .70 | .52 | .72 | .43 | .74 | .28 | 0 | 0 | 0 | .22 | Killed by D.b. 8/28 |
| | Total | | 4.74 | 4.42 | 4.89 | 4.12 | 6.41 | 2.57 | 0 | 0 | .07 | .22 | |
| | Aver. | | 1.18 | 1.10 | 1.22 | 1.03 | 1.60 | .64 | 0 | 0 | .02 | .05 | |

In the preliminary report (Page 8) it was shown that about 96% of the insect-killed trees up to October 1926 had made slight or no growth after the fire. In the trees surviving after 1926 on Plot 1, it is evident that 4 trees killed by the beetles had made scarcely any recovery during the period 1925-1928; while the 6 living trees were rapidly building back toward their normal vigor, although the growth rate in 1928 was still below that for any of the five seasons preceding the fire.

ATTRACTION OF BARKBEETLES TO FIRE-INJURED TREES

The idea has often been accepted that the smoke of forest fires or the odors that arise from freshly-scorched foliage and cambium are directly attractive to barkbeetles in flight, and that they come into a burn soon after the fire occurs because of this attraction.

All the evidence collected in this study indicates that only certain cerambycid and buprestid beetles which attack dead and dying material concentrated in numbers on the burn immediately after the fire. *Dendroctonus valens* was found attacking the base of fire-scorched trees within a few weeks after the fire occurred, but seldom succeeded in killing the trees unless the attack was followed by that of other barkbeetles. The western pine beetle did not become abundant in the burn until late in the summer of 1925, or more than a year after the fire.

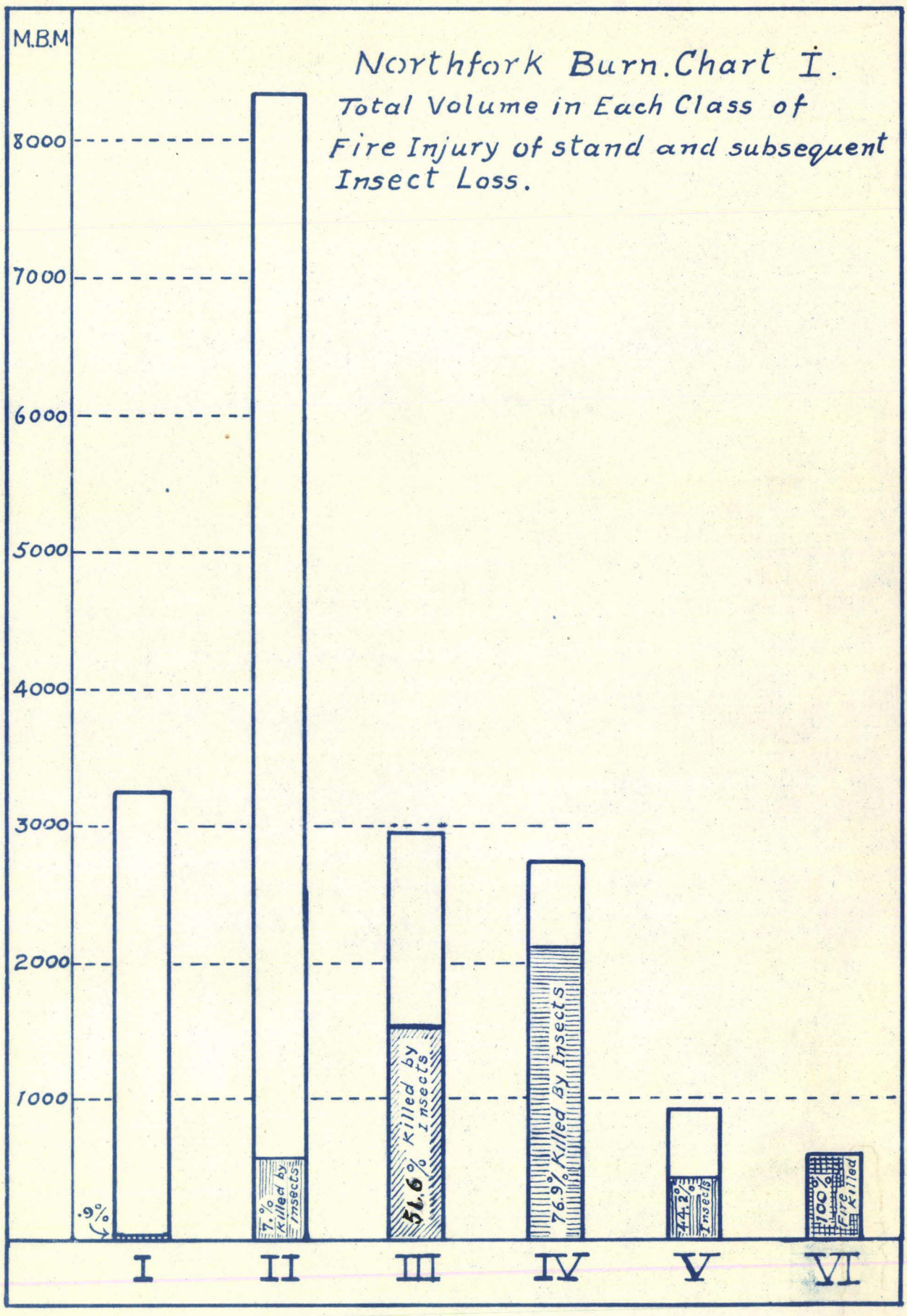
The attraction of primary barkbeetles to fire-injured trees is apparently an indirect one, due to the suppression of growth which renders the tree susceptible to attack. Just how or why this effect upon the growth rate of the tree attracts beetles is not known; but it has been adequately shown that the trees which received the greatest setback in growth rate are the ones selected by the beetles.

As a check upon this point an experimental burn was outlined and carried out by Person in the spring of 1927. On April 29 a group of 9 yellow pines, ranging from 20 to 30 inches d.b.h., were scorched by burning brush around their bases. The fire reached to the crown of some trees and resulted in injury representing all classes from II to V. The following is a summary of developments to October 1928:

| Tree No. | Class of Fire Injury | Insect Attacks | Condition Oct.'28 |
|---|---|---|---|
| KB21 | II | None | Living |
| KB27 | II | " | " |
| KB28 | II | " | " |
| KB29 | II | " | " |
| KB26 | III | " | " |
| KB25 | IV | " | " |
| KB22 | V | D.valens, 5/15/27 | " |
| KB23 | V | D.brevicomis, 9/1/27 | Dead |
| KB24 | V | " 9/20/27 | " |

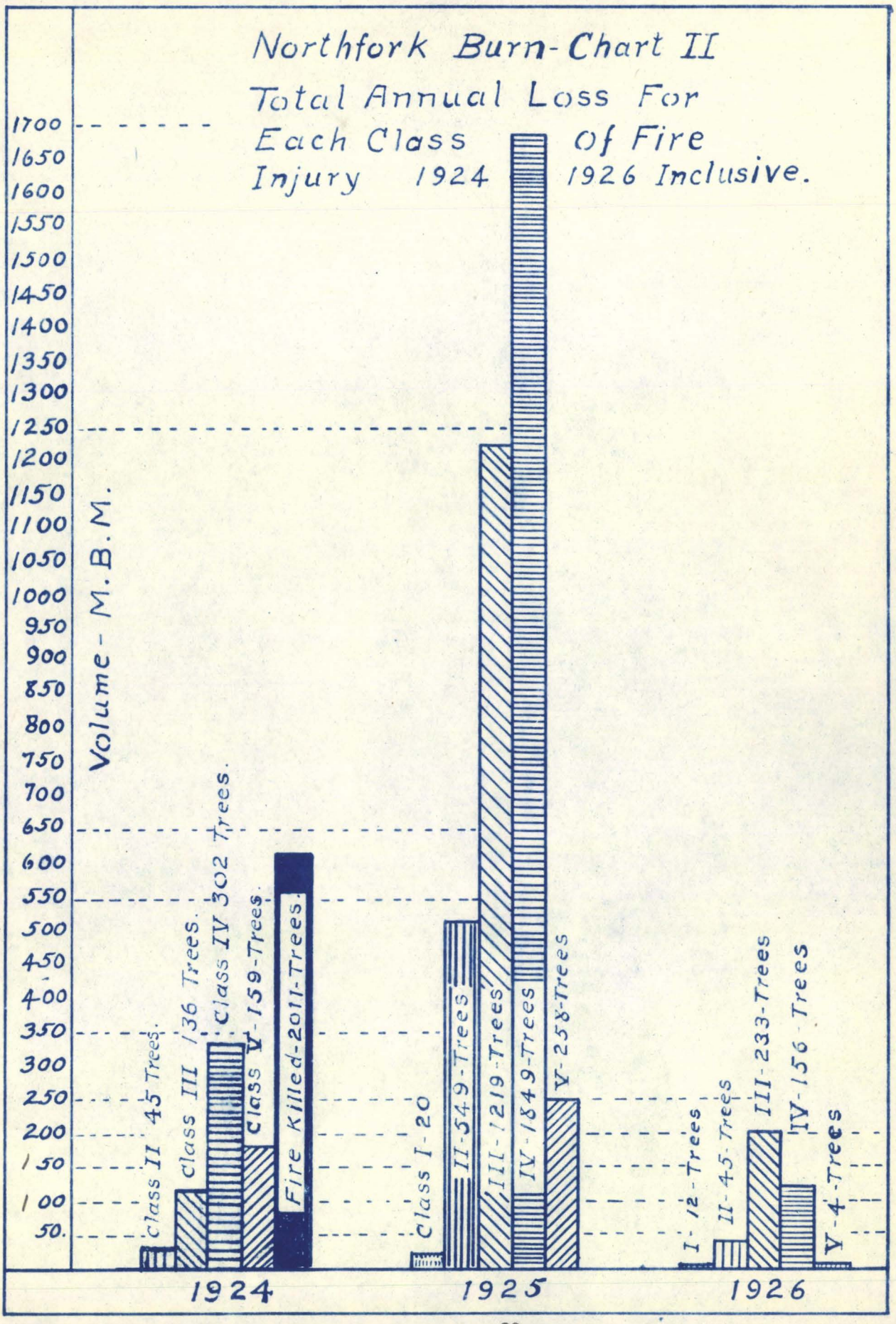
The main flight of adults from the overwintering broods of D. brevicomis occurred within two weeks following the date of this fire, April 29, 1927. However, no attacks of this beetle developed on the fire-injured trees until September 1, four months later. The second tree was attacked more than 4½ months after the fire. It seems apparent that any attractive odors due to the fire itself had disappeared by September. In the meantime the checking of growth during the 1927 season caused at least two of the fire-injured trees to become attractive to the beetles.

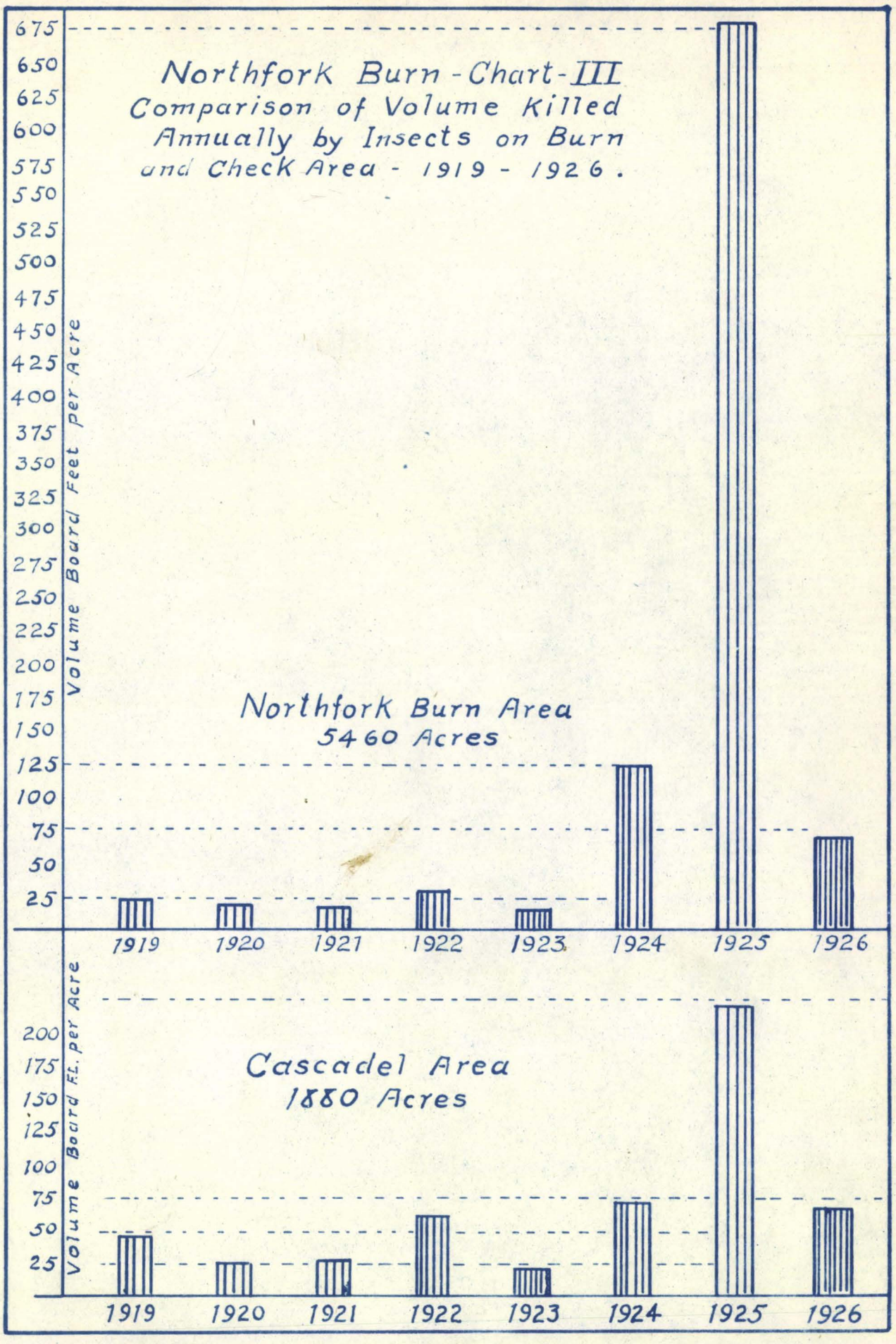
10

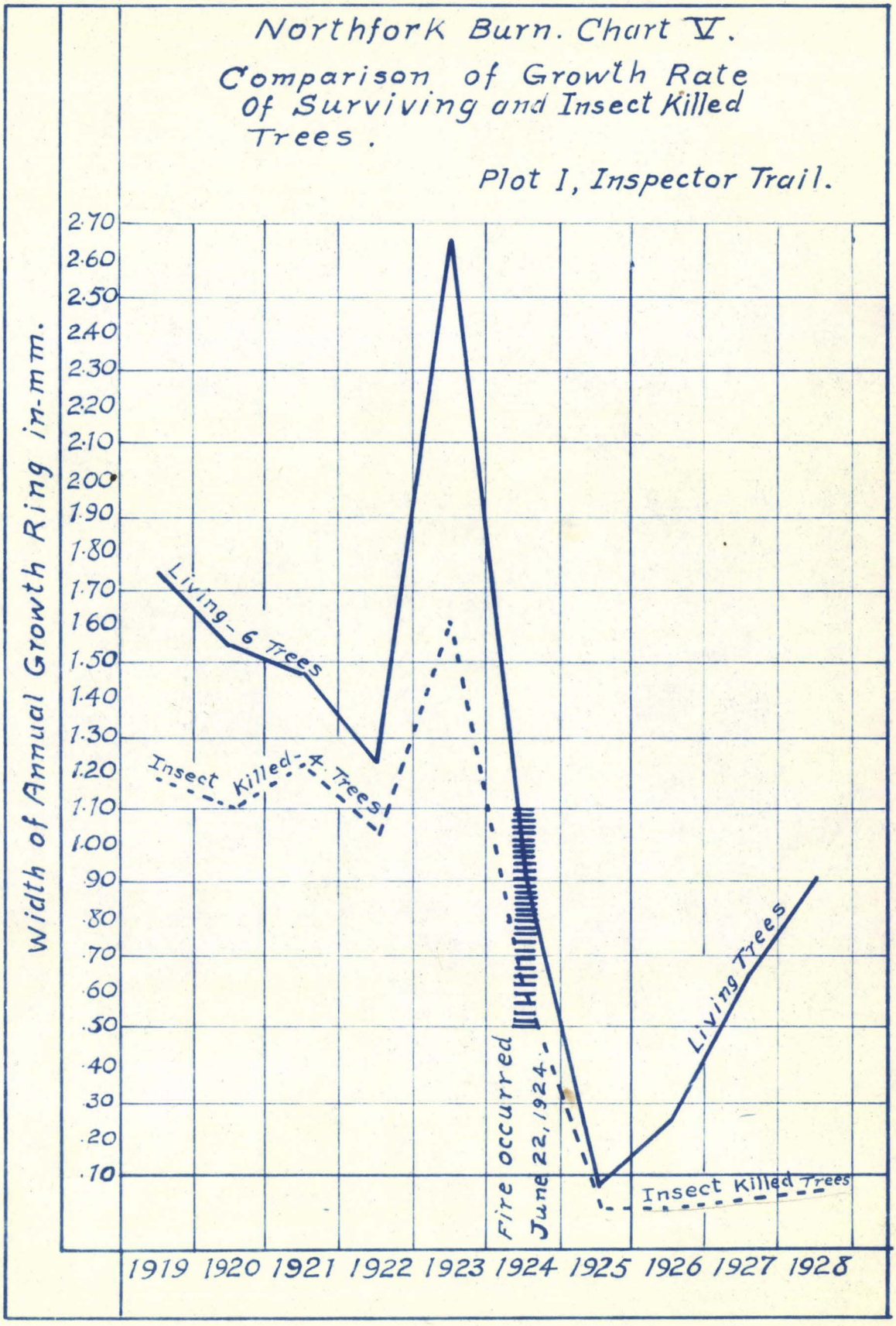


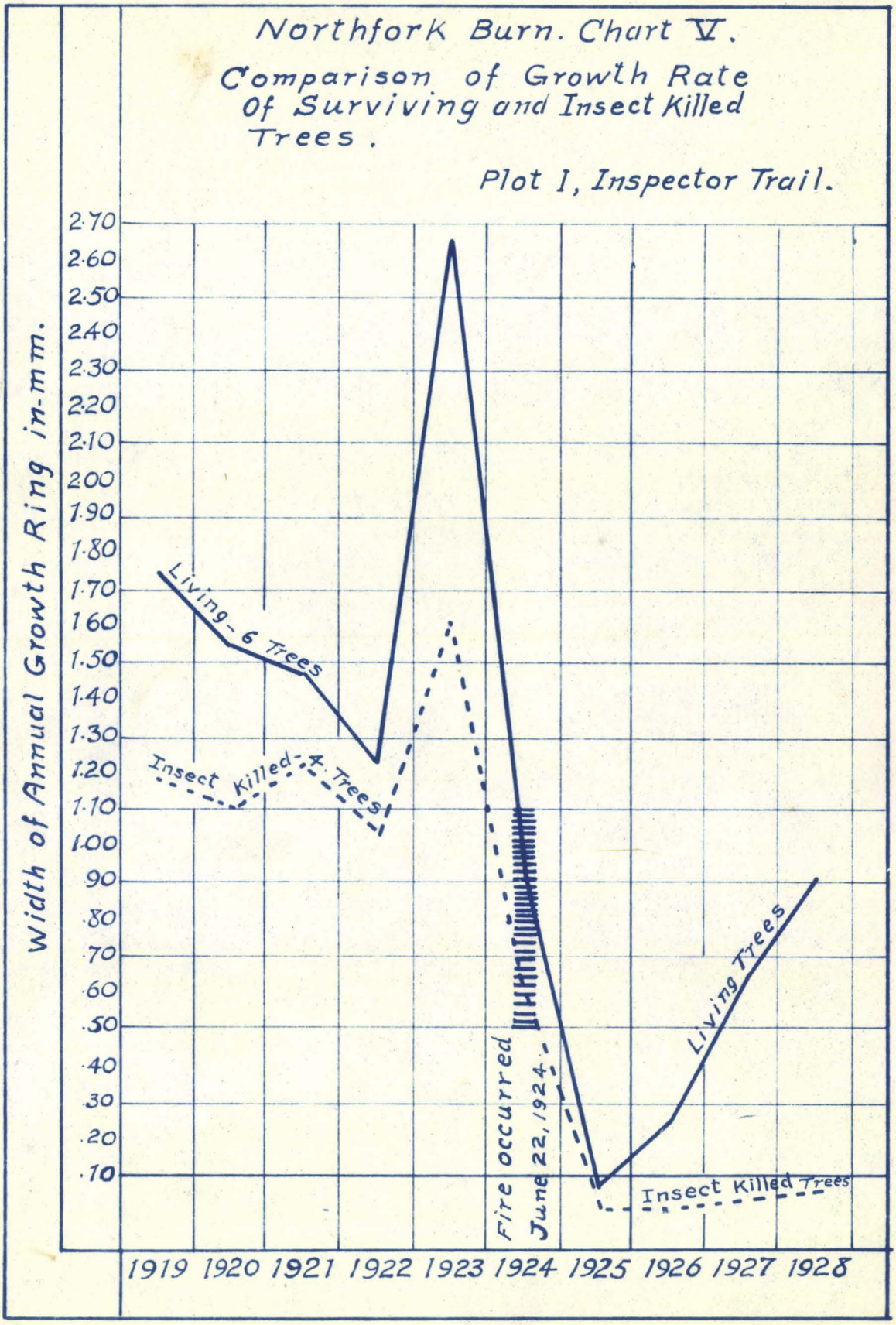

Northfork Burn. Chart I.

Total Volume in Each Class of Fire Injury of stand and subsequent Insect Loss.


Northfork Burn-Chart II
Total Annual Loss For
Each Class of Fire
Injury 1924 1926 Inclusive.
Volume - M.B.M.
1700
1650
1600
1550
1500
1450
1400
1350
1300
1250
1200
1150
1100
1050
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50.
Class II 45 Trees.
Class III 136 Trees.
Class IV 302 Trees.
Class V-159-Trees.
Fire Killed-2011-Trees.
Class I-20
II-549-Trees
III-1219-Trees
IV-1849-Trees
V-258-Trees
I-12-Trees
II-45-Trees
III-233-Trees
IV-156-Trees
V-4-Trees
1924
1925
1926


Northfork Burn - Chart - III
Comparison of Volume Killed Annually by Insects on Burn and Check Area - 1919 - 1926.
Volume Board Feet per Acre
675
650
625
600
575
550
525
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
Northfork Burn Area
5460 Acres
1919
1920
1921
1922
1923
1924
1925
1926
Volume Board Ft. per Acre
200
175
150
125
100
75
50
25
Cascadel Area
1880 Acres
1919
1920
1921
1922
1923
1924
1925
1926


Northfork Burn. Chart V.
Comparison of Growth Rate Of Surviving and Insect Killed Trees.
Plot I, Inspector Trail.
Width of Annual Growth Ring in mm.
2.70
2.60
2.50
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
Living - 6 Trees
Insect Killed - 4 Trees
Fire occurred June 22, 1924
Living Trees
Insect Killed Trees
1919 1920 1921 1922 1923 1924 1925 1926 1927 1928


Northfork Burn. Chart V.
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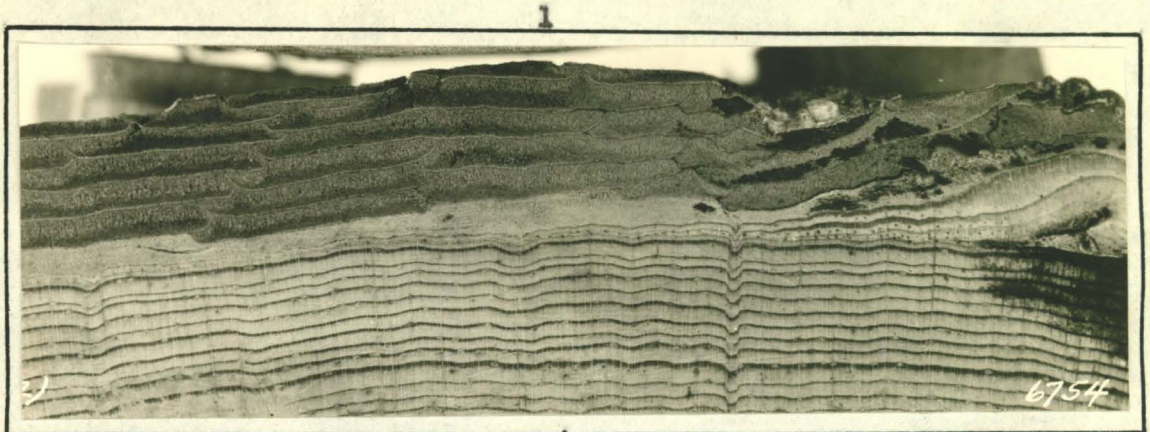
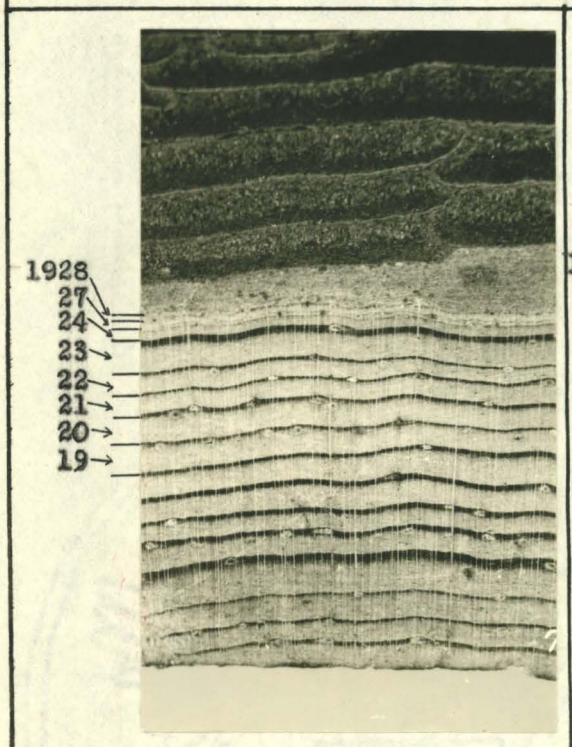
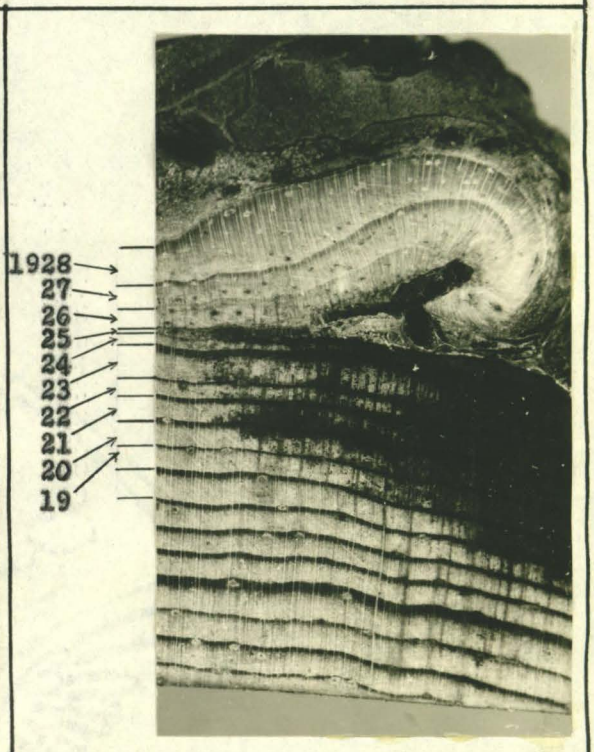
Plot I, Inspector Trail.
Width of Annual Growth Ring in mm.
2.70
2.60
2.50
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
Living - 6 Trees
Insect Killed - 4 Trees
Fire occurred June 22, 1924
Living Trees
Insect Killed Trees
1919 1920 1921 1922 1923 1924 1925 1926 1927 1928

1




2 3

PLATE I NORTHFORK BURN STUDY

Section from Tree No. 96, Inspector Trail Plot, showing growth rings. This tree, representing Class IV fire injury, was still surviving in October 1928.

1. Section taken in October 1928 along side of marking blaze made in July 1924. Growth rings from 1925-1928 are all,visible in the healingcallus formed around edge of scar. These rings diminish as distance from scar increases. The rings for 1925 and 1926 disappear entirely.

2. Enlargement of No. 1, showing section about $2\frac{1}{2}$ inches from scar. The 1925 and 1926 rings are missing at this point.

3. Enlargement of No. 1, showing rings in healing callus near scar. Rings for all seasons since 1924 are visible in this section.

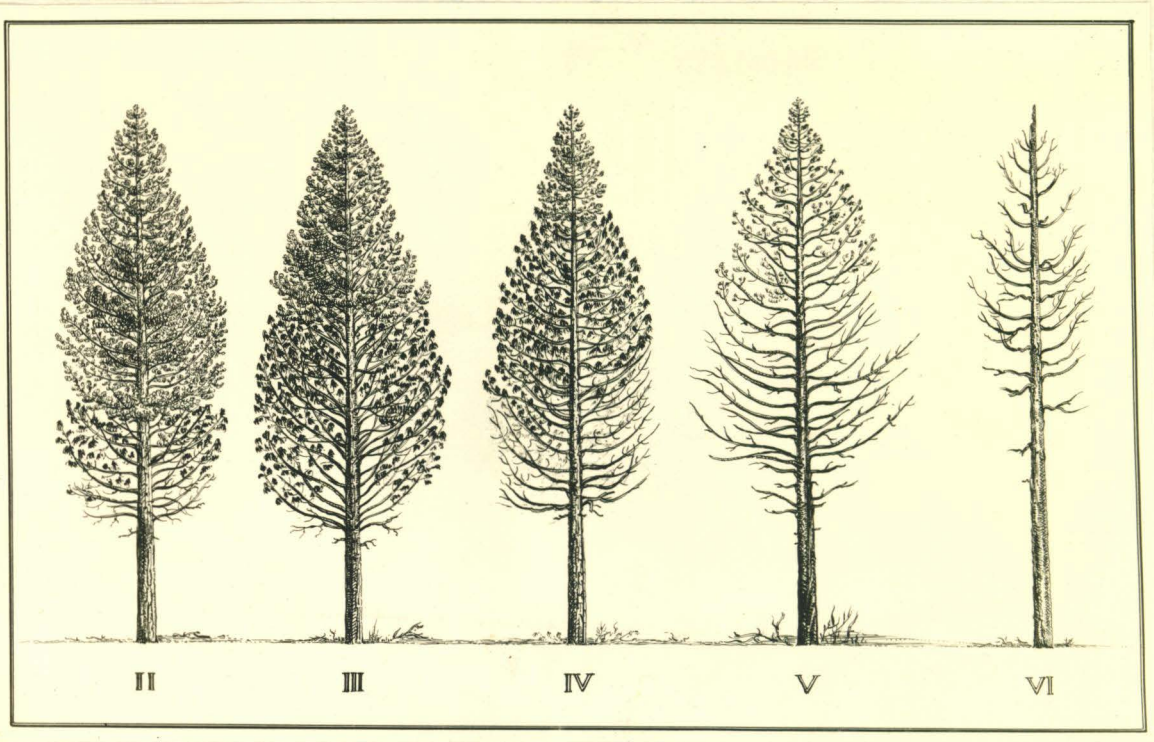



PLATE II, NORTHFORK BURN STUDY
Representation of injury classes recognized after fire. Drooping needles represent foliage scorched but not burned off.

Class II. Less than 25% of crown defoliated. This class averaged 1460 board feet per tree. 7.% of timber volume in class was killed by insects subsequent to fire.

Class III. 25 to 50% of crown defoliated. This class averaged 912 board feet per tree. 51.6% of timber volume in class was killed by insects subsequent to fire.

Class IV. 50 to 75% of crown defoliated. This class averaged 795 board feet per tree. 76.9% of timber volume in class was killed by insects subsequent to fire.

Class V. 75 to 100% of crown defoliated. Terminal buds near top not injured. This class averaged 324 board feet per tree. 44.2% of timber volume in class was killed by insects subsequent to fire. This class included many small vigorous trees with lower foliage scorched but not burned off and with little or no cambium injury. In the larger trees cambium scorching occurred on trunk and limbs.

Class VI. 100% of crown defoliated, terminal buds killed, cambium more or less severely scorched. This class averaged 304 board feet per tree. 100% of timber volume killed by fire. Barkbeetle attacks occurred in trees with green strips of cambium on main trunk, but all trees included in this class were considered to have been killed as a result of primary fire injury.